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SPECIFICATIONS AND CLAIMS OF PATENT APPLICATION

Power Cogeneration System And Apparatus Means For Improved High Thermal Efficiencies and Ultra-Low Emissions

BACKGROUND OF THE INVENTION

To achieve a goal of significantly reducing a power cogeneration system's mass emission rate of the "greenhouse gas" (carbon dioxide) by a significant percentage amount, it is necessary to proportionally increase the thermal efficiency of a power unit apparatus' conversion of fuel energy to developed mechanical power and useful applied recoverable thermal energy which therein proportionally reduces the amount of combusted hydrocarbon fuel required to provide the described energy conversion.

It has been well known and practiced for decades that higher humidity air and injected water or steam commingled with conventional air combustion gases increases combustion flame speeds and fuel combustion thermal efficiencies within gas turbines and other fuel combustion burner apparatus using air/fuel combustion. It has also been well known and practiced that partially re-circulating combustion flue stack gases containing carbon dioxide (hereafter may be referred to as CO.sub.2) back into a combustion chamber results in a reduced level of nitrogen oxides (hereafter may be referred to as NO.sub.x) within the fuel combustion exhaust gases. Due to the high

temperatures and speed of completed fuel combustion, the scientific community has been unable to reach a consensus as to precisely what series of altered chemical reactions occur when water vapor and/or carbon dioxide is introduced into a combustion chamber assembly or subassembly device.

Oxy-fuel combustion burners have been employed for many years in the steel and glass making industries to furnish desired 3000+ degree Fahrenheit combustion gas temperatures into furnaces to avoid the production of high NO.sub.x emissions, but at the expense of high carbon monoxide (hereafter may be referred to as CO) emissions. Both the present air separation art methods' high production energy costs of producing acceptable combustion grade oxygen, and the lack of devised combustion system methods to control preset desired oxy-fuel combustion burner or combustion chamber assembly or subassembly uniform maximum temperatures, have collectively curtailed oxy-fuel combustion applications within present fuel thermal energy to power_energy conversion facilities.

Conventional gas turbines must be de-rated from their standard ISO horsepower or kW ratings at ambient temperatures exceeding 59° F, and/or at operating site altitudes above sea level. Thus, during summer's peak power demand periods, when the ambient temperature can increase to 95° F or greater, up to 20% to 25% horsepower derations of a conventional gas turbine's ISO rating can occur. It is obviously desirable that a power turbine /generator unit apparatus within a cogeneration system not be susceptible to such combined on-site ambient temperature and altitude derations when summer season peak power demands occur, or at any other time.

The current and future projected increasing costs of purchased utility electric power and natural gas (or liquid hydrocarbon fuel) and the accepted projected future trend in

the future of "distributed power" and/or power cogeneration facilities, coupled with present and future environmental constraints on fuel combustion exhaust emissions, collectively requires substantially improvements over currently available best available technology (hereafter may be referred to as B.A.T.). It can be expected that the number of new turbine powered 'cogeneration facilities in the world will be significantly greater than the number of turbine powered 'combined-cycle' facilities that are devoted purely to the production of electric power. The referenced 'cogeneration facilities' are not new in concept. Such energy saving facilities became highly popular in the 1970's (then referred to as 'Total Energy Plants') and were aggressively promoted by many natural gas utilities. Reciprocating gas engine-driven generator sets were the predominant producers of prime power and utilized waste heat. These 'Total Energy Plant' facilities efficiently provided electricity, hot water or steam for domestic hot water and building heating requirements, and chilled water for air conditioning. 'Total Energy Plants' were widely applied to serve hospitals, universities, large office buildings or building complexes, shopping centers, hotels, food processing plants, and multi-shift manufacturing and industrial facilities, etc. The 50 plus years old predecessor to the 'Total Energy Plant' concept was the central electric power and steam plants that continue to currently serve some large eastern US cities, and more predominantly European cities and metropolitan areas. Predominantly, 'Total Energy Plants' and current cogeneration facilities have predominantly had less than 100 psig utility supplies of natural gas available to their facilities.

It is not unusual that present art cogeneration facilities can require fuel gas compression apparatus assemblies to supply adequate fuel pressure to the employed cogeneration power units, with the said fuel gas compression consuming

approximately 5% of the gross electric power produced by the current art power cogeneration facility. It is therefore desirable that power cogeneration facilities incorporate a fuel energy to power and useful heat energy conversion method that requires low gas supply pressures.

When Brayton Simple Cycle gas turbines operate as mechanical power drive sources to electric generators and other mechanically driven devices, atmospheric air is compressed and mixed with hydrocarbon gases or atomized hydrocarbon liquids for the resulting mixture's ignition and combustion at approximately constant pressure. To produce power, the hot combustion and working motive fluid gases are expanded to near atmospheric pressure across one or more power extraction turbine wheels, positioned in series.

The majority of Brayton simple open-cycle aero-derivative-style Low-NO.sub.x art gas turbines are predominantly presently limited in achieving shaft output horsepower rating with 26% to 39% thermal efficiencies, whereas most simple cycle industrial-style Low-NO.sub.x art gas turbines are predominantly presently limited in demonstrating shaft output horsepower rating with 27% to 34% thermal efficiencies. The aero-derivative turbine engine's higher efficiencies are achieved when the gas turbines operate with compressor ratios ranging from 14 to 35 and predominant first stage turbine inlet temperatures ranging from 2000° to 2300° F.

Existing conventional applied art gas turbines employ combustion chamber air/fuel combustion chemical reactions, wherein the elements of time and high peak flame temperatures increase the presence of disassociation chemical reactions that produce the fugitive emissions of (hereafter may be referred to as CO) and other chemical reactions that produce NO.sub.x.

The best available applied turbine low NO.sub.x combustion technology for limiting gas turbine NO.sub.x emissions, using stiochiometric air/fuel primary combustion reaction chemistry means, still results in the production of NO.sub.x and CO that are no longer acceptable for new power or energy conversion facilities in numerous states and metropolitan environmental compliance jurisdictions. With the conventional gas turbine's use of compressed atmospheric air as a source of oxygen (hereafter may be referred to as O.sub.2) which acts as a fuel combustion oxidizing reactant, the air's nitrogen (N.sub.2) content is the approximate 78% predominant mass component within the cycle's working motive fluid. Due to its diatomic molecular structure, the nitrogen molecules are capable of absorbing combustion heat only through convective heat transfer means predominantly resulting from their collisions with higher temperature combustion gas molecules or higher temperature interior walls of the combustion chamber.

Despite the very brief time it takes for conventional gas turbine to reach a average molecular primary flame combustion zone gas equilibrium temperature of less than 2600° F within its combustion chamber assembly or subassembly, there are sufficient portions of the combustion zone gases that experience temperatures in excess of 2600° F to 2900° F for an ample period of time for the highly predominate nitrogen gas to enter into chemical reactions with oxygen that produce nitrogen oxides. The same combined elements of time and sufficiently excessive high flame temperature permit carbon dioxide to enter into dissociation chemical reactions that produce carbon monoxide gas.

To achieve a goal of greatly reducing a turbine power unit's NO.sub.x and CO fugitive emissions, it is necessary to alter both the fuel combustion chemical reaction

formula and the means by which acceptable combustion flame temperatures can be closely controlled and maintained within a power turbine unit's fuel combustion assembly. Maintenance of an acceptably low selected fuel combustion peak gas temperature at all times and throughout all portions of within the combustion assembly, requires a change in the means by which the heat of combustion can be better controlled and more rapidly distributed uniformly throughout the gases contained within the fuel combustion assembly.

Summary of the Invention

To achieve both power turbine ultra-low NO.sub.x and CO exhaust emissions as well as reduced "greenhouse gas" CO.sub.2 emissions and enhanced simple-cycle operating thermal efficiencies, the inventor's AES gas turbine power cycle system and apparatus is described in U.S. Patent # 6,532,745 dated March 18, 2003. The cited invention's further described partially-open gas turbine cycle contains multiple heat recovery devices for transferring waste heat to varied process gases and steam resulting in a cogeneration facility overall maximum thermal efficiency that "may approach 100%".

The present invention describes the means by which the cited partially-open AES turbine power cycle system and apparatus devices can be incorporated within an improved power cogeneration process having simplified system apparatus means and that can further achieve increased power cogeneration process and system thermal efficiencies which may exceed 115%.

The present invention further describes an added alternative process stream and system apparatus means that can be employed within an improved power cogeneration system design, the added alternative process stream and system apparatus means

incorporating portions of the heater cycle system and apparatus content cited in the inventor's U.S. Patent application 10/394847 filed March 22, 2003 and titled "Partially-Open Fired Heater Cycle Providing High Thermal Efficiencies and Ultra-Low Emissions".

The addition of the added alternative process stream and system apparatus means to the presented turbine engine type based cogeneration system, as later further described and shown in Figure 2, may increase the presented power cogeneration process and system's overall thermal efficiency to greater than 115%.

To achieve the power cogeneration process and system's ultra-low fugitive exhaust emissions, the presented power cogeneration process and system employs a partially-open gaseous thermal fluid energy cycle and apparatus assembly devices that provides a continuous controllable mass flow rate of described recycled or "recirculated" superheated predominant mixture of carbon dioxide and water vapor, the mixture being in identical mixture Mol percent proportions as each said molecular gas component occurs as a product of chemical oxy-fuel combustion reactions from the gaseous or liquid hydrocarbon fuel employed.

To achieve the power cogeneration process and system's ability to employ gaseous hydrocarbon fuels, other than gas utility distribution quality natural gas, the cited gaseous fuels (alternately containing toxic and/or difficult to combust hydrocarbon molecular gases) can be rapidly carried through useful fuel energy to recoverable heat conversion and/or completed incineration. The inventions provided process and system apparatus controls the primary and secondary combustion zones temperature whereby completed difficult fuel combustion can take place. The invention's preferred example 2400° F primary and outer secondary zone combustion temperature provides a desired

7.585 greater chemical reaction speed rate between a fuel and oxygen than that occurring at 1800° F. As repeatedly verified by John Zink Research in applied research, the reaction rate formula is:

$$\text{Reaction Rate Increase} = (N) = \frac{[(2400^\circ\text{ F}+460) \div (1800^\circ\text{ F}+460)] - 1}{.035}$$

Provided herein is both a partially-open turbine power cogeneration process and system with apparatus means for use therein of either the provided example modified conventional gas turbine unit configurations, or use therein of the alternative unconventional turbine assembly unit apparatus configurations that can utilize separate existing low cost mechanical equipment apparatus assembly components and combustion chamber assembly or subassembly devices. The cited assembly components need not to be designed for, nor applied to, either the manufacture of conventional gas turbines nor the said components and combustion chamber assemblies or subassemblies incorporation into facility designs of current technology gas turbine cogeneration systems (or combined-cycle systems). The cited combustion chamber assemblies or subassemblies devices are those wherein fuel combustion occurs at pressures greater than 1.5 bar absolute.

The invention's combined employed cited partially-open gas turbine cycle system and apparatus, and alternative added cited heater cycle system and apparatus portion into the present invention therein provides for a commonly 'shared non-air' working motive fluid means that is essential to the 95% to 100% reduction of NO.sub.x, and CO mass flow emissions from those of conventional Low-NO.sub.x designed gas turbines and/or other conventional fuel combustion burner devices that can be applied within existing art power cogeneration systems methods and employed apparatus devices.

It is an objective of the present invention's improved power cogeneration process and system and apparatus means to provide a new benchmark standard for B.A.T. in achieving combined highest thermal efficiencies, lowest emissions, and lowest auxiliary facility operating power consumptions within a overall operating power cogeneration facility.

It is a further objective of this invention to provide the means by which the power cogeneration process and system's production of steam or hot water, and/or the heating of process fluids, is not limited by the amount of a turbine /generator or mechanical drive train's availability of recoverable exhaust waste heat that can be derived from a given production level of electric power or mechanical horsepower.

It is a further objective of this invention to provide the means by which the power cogeneration process and system's presented alternative apparatus devices can comprise unconventional individual power train unit components that can be adapted to (but not limited to) individual unit power generator ratings of 200 kW to 30 MW+ to satisfy most cogeneration facilities' installed individual unit power rating requirements.

It is a further objective of this invention to provide the collective means by which deviations from the presented invention's example operating conditions can be made to best accommodate a facility designer's incorporation of existing models of other facility auxiliary equipment that can be further incorporated into a specific design of cogeneration facility. Other facility auxiliary equipment may comprise currently manufactured absorption chillers or mechanically-driven refrigeration chillers that have been conventionally or similarly applied in related waste heat recovery power facilities for over 30 years.

It is a further objective of the present invention's cogeneration process and system apparatus devices to accomplish both a highly accelerated oxy-fuel combustion process and the added capabilities to separately control both a preset maximum primary combustion zone temperature and the tertiary zone exhaust gases temperature supplied to the example gas turbine hot gas expansion turbine assembly. This satisfied objective eliminates the elements of time and high degree of temperature that is required for endothermic dissociation chemical reactions to occur that produces both NO.sub.x and CO within the conventional air-fuel combustion product gases.

It is a further objective of the present invention of improved cogeneration process and system apparatus that the example modified conventional gas turbine assembly or alternative unconventional re-configured turbine train apparatus assembly can be capable of achieving an additional 35% to 40% in process and system thermal efficiencies than are available in current art B.A.T. gas turbine power cogeneration facilities.

It is a further objective of the present invention of improved power cogeneration process and system and apparatus means, that the cited incorporated partial-open example gas turbine cycle system and apparatus means of preferred high efficiencies can employ (but not limited to) gas compression ratios of 2.4 to 6.4 (2.1 to 6.5 Bar operating pressure). These gas compression ratios can be compared to conventional gas turbines having varied employed compression ratios of approximately 9 to 35.

It is a further objective of the present invention of improved power cogeneration process and system apparatus assemblies can provide the maximum cogeneration thermal efficiencies with facility fuel gas supply pressures of less 100 psig (6.9 bar).

It is a further objective of this invention to provide the means wherein, during a steady-state power cogeneration process operation, that the 'open portion' of the 'partially-open' gaseous thermal fluid energy cycle process therein provides an approximate atmospheric-vented gas mass flow that can be approximately 5 to 8% of the total working motive fluid mass flow rate as contained within the 'closed portion' of the improved power cogeneration process system.

It is a further objective of this invention to provide the process and system means whereby all apparatus assemblies and devices can collectively include appropriate safety sensor/transmitter and fluid flow control devices. The presented invention's power cogeneration process and cycle gas streams, streams of supplied fuel and predominant oxygen, and contained apparatus assembly devices can be monitored and controlled for safe operation, during all operations encompassing variations in electric power generation demands and thermal fluid heat energy extraction demands from remote supplied steams of steam or hot water, or process fluids. It is a further objective of this invention to provide the combination of power cogeneration process and system apparatus and control devices by which a non-distribution quality of gaseous hydrocarbon fuel (containing toxic and/or difficult to combust hydrocarbon molecular gases) can be rapidly carried-forth through oxy-fuel combustion to a useful heat energy conversion and/or completed incineration without emitted toxic gas emissions to atmosphere.

The following nine embodiments comprise the subject matter of this invention:

First Embodiment

The working motive fluid of this invention's power cogeneration process and system comprises a continuous superheated vapor mixture of predominant carbon dioxide and

water vapor in identical Mol percent ratio proportions as the molecular combustion product components Mol percent ratio proportions are produced from the combustion of the gaseous or liquid hydrocarbon employed fuel.

Within the predominately-closed portion of the presented invention's cited power cogeneration process' partially-open gaseous thermal fluid energy cycle, the re-circulated exhaust gas is routed from an exhaust gas distribution manifold (the exhaust gas having a small degree of superheat temperature and positive gage pressure supply) into the inlet of the primary recycle gas compressor. The exhaust gas recycle compression function can be performed by a more typical axial compressor section used for air compression within a conventional gas turbine unit, or it may be a separately power driver device-driven compressor of the axial, centrifugal, or rotating positive displacement type. Either described type of compression can incorporate means of flow control available within the compressor or by its driver's varied speed, with flow changes being initiated by a power cogeneration PLC type control panel containing programmable logic microprocessors.

The cited type of compressor can increase the example gas turbine power engine unit's recycled or recirculated exhaust's absolute pressure by a ratio range of only 2.4 to 6.4 to achieve a relatively high example gas turbine unit "stand-alone" simple-cycle thermal efficiency, but in the case of the cited gas turbine unit's incorporation into the invention's cited combined power cogeneration process and system apparatus assembly devices, the gas turbine unit is not limited to operations within these said ratios.

As shown in Table 1, between the example gas turbine fuel combustion pressures of 45 psia and 75 psia, the cited gas turbine unit's "stand-alone" simple-cycle thermal

efficiencies can range between 35.16% and 43.24%. Between 75 psia and 90 psia oxy-fuel combustion burner assembly pressures (with the common individual primary recycle compressor and hot gas expander power turbine assembly efficiencies of 84% and a stage 1 turbine inlet temperature of 1800° F), the cited gas turbine unit "stand-alone" (simple-cycle) efficiencies can begin to decline.

TABLE 1

Combustion Operating Pressure	Gas Turbine Gas Inlet Temperature	Gas Turbine Exhaust Temperature	Gas Turbine Net Output Horsepower	Gas Turbine Fuel Rate Btu/HP-Hr.	Thermal Efficiency %*
45 psia	1800° F	1471° F	2859	7237	35.16
60 psia	1800° F	1391° F	3458	5983	42.54
75 psia	1800° F	1331° F	3515	5885	43.24
90 psia	1800° F	1284° F	3406	6075	41.89

*With a 1 Mol/minute methane gas fuel rate

The recirculated and re-pressurized cogeneration process exhaust gas (hereafter can be referred to as "primary re-pressurized recycle gas". Within the cited power cogeneration process' partially-open gaseous thermal fluid energy cycle, the re-pressurized recycle gas is discharged from the primary recycle gas compressor at an increased temperature and pressure through a conduit manifold containing both a side-branch connection and first and second parallel conduit end-branches' flow-controlled streams. The cited conduit manifold side-branch supplied controlled low mass flow stream of re-pressurized recycle gas can be reduced in temperature within an air-cooled exchanger prior to the stream flow's entry into one or more preferred partial-premix subassembly contained within each turbine's oxy-fuel combustion chamber assembly or subassembly. Within each referred partial-premixer assembly, the reduced

temperature primary re-pressurized recycle gas stream can be homogenously pre-mix blended with the supply stream of predominant oxygen that is also is also supplied to the preferred partial pre-mix subassembly and/or premix blended with the supply stream of fuel.

The fore-cited first and second parallel conduit end-branches flow-controlled streams have end-connectivity respectively to the inlets of first and second headers of the power turbine exhaust gas waste heat recovery unit (hereafter may be referred to as WHRU) exchanger of counter-current flow gas to gas heat exchange design. A predominate flow-controlled portion of the power turbine's developed high temperature exhaust is flow-directed through the cited WHRU exchanger for its recoverable heat transfer into the primary re-pressurized recycle gas stream that thereafter is downstream re-admitted as a 'working motive fluid' into the gas turbine's oxy-fuel fired combustion chamber assembly.

This power turbine exhaust gas WHRU exchanger can be capable, with the particular example of a methane fuel combustion chamber pressure of 60 psi absolute and a 1800° F first stage hot gas expansion power turbine inlet temperature, of raising the temperature of the primary re-pressurized recycle gas within the turbine exhaust gas WHRU exchanger to an approximate maximum 1350° F temperature. With these operating conditions and assumed individual compressor and hot gas expansion turbine efficiencies of 84%, a resultant simple-cycle turbine thermal efficiency of 42.5% can be achieved.

Thereafter, the 1350° F highly superheated and re-pressurized recycle gas individual streams are referred to as "working motive fluid" gas streams. The first controlled stream of working motive fluid can be routed and separately flow-divided as

required to the internal tertiary blending zone contained within each of one or more oxy-fuel turbine combustion chamber assembly or subassembly that can be conventionally positioned radially about the centerline axis of the power turbine unit assembly. The second controlled stream can be separately flow-divided as required for passage into one or more preferred partial-premixer sub-assemblies contained within one or more oxy-fuel turbine combustion chamber assembly.

Within the presented power cogeneration process and system, a lesser flow controlled portion of the total power turbine exhaust flows through the waste heat recovery steam generator (hereafter may be referred to as WHRSG) exchanger or waste heat recovery process fluid (hereafter may be referred to as WHRPF) exchanger.

Second Embodiment

From the First Embodiment's "the re-circulated turbine exhaust gas is routed from a exhaust gas distribution manifold (the turbine exhaust gas having a small degree of superheat temperature and positive gage pressure supply) into the inlet of the primary recycle gas compressor", the cited cogeneration process re-circulated exhaust gas within the exhaust distribution manifold comprises the discharge exhaust gas from a second WHRSG or WHRPF exchanger upstream that is inlet-connected to a re-circulated exhaust gas manifold that conveys the combined reduced temperature exhaust gases originating from both the WHRU exchanger and the first parallel-positioned WHRSG or WHRPF exchanger into which the total cogeneration system's recoverable high temperature waste exhaust gases are first inlet-connected.

Either the second WHRSG or second WHRPF exchanger can perform the initial heating of supplied streams from either a facility's steam or hot water feed circuit or a process fluid stream prior to either of these streams having further downstream

connectivity to the fore-described high temperature exhaust waste gases first WHRSG exchanger or WHRPF exchanger.

Third Embodiment

From the First Embodiment's cited re-circulated turbine exhaust from the exhaust gas distribution manifold supplied to the inlet of the primary recycle gas compressor, the exhaust gas distribution manifold has a end manifold alternative system connection point and two side-branch flow delivery connections. The first side-branch conduit provides the greatly predominant flow of re-circulated exhaust gas into the inlet of the primary recycle gas compressor, and the second side-branch conduit directs the controlled flow of excess of re-circulated exhaust gases to atmosphere during steady-state operation of the presented system. This flow of excess cited re-circulated exhaust gases to atmosphere constitutes the "Open Portion" of the presented partial-open power cogeneration process and system. The system steady-state condition's controlled mass flow rate in which the re-circulated exhaust that is vented to atmosphere is equivalent to the combined mass rates at which the fuel and the predominant oxygen gas streams enter the invention's provided oxy-fuel combustion system process' partially-open cycle .

Fourth Embodiment

From the First Embodiment's cited "The second controlled stream can be separately flow-divided as required for passage into one or more preferred partial-premixer sub-assemblies contained within one or more oxy-fuel turbine combustion chamber assembly.", each partial-premixer sub-assembly having the following introduced controlled streams: fuel; a predominant oxygen stream which originates from an adjacent facility area containing a preferred highly electric energy efficient modular air

separation system; First Embodiment described air-cooled primary re-pressurized recycle gas; and second stream of working motive fluid. These individual flow controlled conduit streams at differential pressures and velocities are collectively admitted through their respective partial-premixer inlet conduit means for preferred selective pre-mixing and homogeneous blending at points of admittance into the primary and outer secondary combustion flame zones within each turbine oxy-fuel combustion chamber assembly.

To establish primary combustion temperatures that do not exceed the example preferred maximum 2400 F, one of several possible acceptable designs of partial-premixer sub-assembly can be one of wherein the oxy-fuel combustion chamber assembly (a specific process or design of which is not within the scope of the presented invention) can internally incorporate both a primary oxy-fuel combustion flame zone and a secondary outer zone wherein a predominant portion of the fore-described second stream of working motive fluid can be introduced into an outermost flow annulus area surrounding the homogeneous mixture admitted from each partial-premixer sub-assembly into the cited primary combustion flame zone for ignition. The secondary outer zone introduced working motive fluid can thereby provide a closely positioned rapid heat-absorbing greater mass shrouding means around each primary combustion flame zone developed within the oxy-fuel combustion chamber assembly. This flame shrouding means can enable the radiant heat energy emanating from the lesser mass of binary gas molecules within the combustion flame to be rapidly distributed to and absorbed uniformly by the described shroud's contained greater mass of identical binary gaseous molecules at the speed of light rate of 186,000 miles per second. The resulting equilibrium temperature within each oxy-fuel combustion chamber assembly's

primary combustion flame zone and secondary zone, based on the controlled flow rate of the second stream of working motive fluid into the oxy-fuel combustion chamber assembly, can be established as being equal to a preset desired example of a maximum 2400° F or other desired preset temperature that is substantially less than the temperature at which NO,sub.x and CO can be formed during endothermic disassociation chemical reactions. The example maximum 2400° F merely represents a conservative maximum temperature to totally avoid the slightest potential of any combined production of extremely small trace amounts of NO.sub.x and companion larger amounts of CO.

Fifth Embodiment

From the First Embodiment's cited "The first controlled stream of working motive fluid can be routed and separately flow-divided as required to the internal tertiary blending zone contained within each of one or more oxy-fuel combustion chamber assembly or subassembly that can be conventionally positioned radially about the centerline axis of the power turbine unit assembly", the first controlled stream of working motive fluid to the tertiary blending zone flow can be introduced into an oxy-fuel combustion chamber assembly's inner annulus area between the chamber assembly's outer casing and an inner liner surrounding each primary oxy-fuel combustion flame zone and outer secondary zone, followed by its flow emanation into the chamber assembly's downstream-positioned tertiary blending zone chamber area through openings in the said inner liner. This tertiary zone introduced mass flow of superheated working motive fluid (of example 1350°F temperature) blends with the example maximum 2400° F equilibrium temperature combined gases emanating from the chamber assembly's primary oxy-fuel combustion flame zone and its outer secondary

zone to thereby produce a resultant example 1800° F final oxy-fuel combustion chamber assembly exhaust equilibrium temperature to the hot gas expansion turbine assembly. The equilibrium temperature of the final oxy-fuel combustion chamber assembly exhaust gases is not limited to 1800° F, and can be controlled by the introduced tertiary working motive fluid mass flow rate and/or fuel mass flow rate to establish any other higher or lower selected operating temperature. The example 1800°F temperature can be chosen to coincide with 10 year old proven power turbine blade metallurgy technology for continuous operation.

Within the one or more hot gas expansion turbine stages, the oxy-fuel combustion chamber assembly's pressurized and highly superheated gases are expanded to create useful work in the conventional form of both turbine output shaft horsepower and (in the case of a conventional modified gas turbine unit configuration) internal horsepower to additionally direct-drive the primary recycle gas compressor. In a conventional 2-shaft style of gas turbine, the primary recycle gas compressor can be shaft-connected to the high-pressure stage section of the power turbine assembly, and the low pressure section of the power turbine assembly with connected output shaft therein provides the turbine power assembly output power to driven equipment. The expanded exhaust gases exit the power turbine assembly at a low positive gage pressure and are further conveyed through conduit means to the fore-described WHRU exchanger and adjacent parallel-position WHRSG or WHRPF exchanger as further described later and shown in Figure1.

Sixth Embodiment

In the Fifth Embodiment's description "In a conventional 2-shaft style of gas turbine, the primary recycle gas compressor can be shaft-connected to the high-pressure stage

section of the power turbine assembly, and the low pressure section of the power turbine assembly with connected output shaft therein provides the turbine power assembly output power to driven equipment.", the presented invention provides an alternative system process and system apparatus devices by which an unconventional turbine power train (comprising individual separate compressor unit assembly, oxy-fuel combustion chamber assembly, and hot gas expansion turbine assembly unit with mechanical shaft output) can be configured to produce mechanical or electrical power within a cogeneration process and system as described later and shown in Figure 2.

The invention's alternative primary recycle gas compressor can be a separately motor-driven or stream turbine-driven compressor of centrifugal or axial type therein comprising one or more stages of compression as required, or a single rotating positive displacement type for the system applied operating conditions. The re-circulated and slightly superheated process cycle exhaust gas stream is re-introduced into the primary recycle gas compressor and increased in pressure and temperature as described for the invention's conventional type gas turbine power assembly. The presented alternative style of primary recycle gas compression drive train generally offers greatly improved capacity control and/or turn-down capabilities, but can be overall less efficient than the conventional type gas turbine assembly's direct-driven axial compressor section.

As described in the Fourth and Fifth Embodiment, the oxy-fuel combustion chamber assembly configuration and functional operation remains unchanged. Rather than the Fifth Embodiment described one or more oxy-fuel combustion chamber assembly being conventionally positioned radially about the centerline axis of the power turbine unit assembly, the presented invention's added alternative process and system apparatus

means can further have a single oxy-fuel combustion chamber assembly that is axially centerline-positioned and can be directed-connected to the hot gas expander power turbine as shown later in Figure 2.

Seventh Embodiment

From the Second Embodiment's cited "...... the cited cogeneration process re-circulated exhaust gas within the exhaust distribution manifold comprises the discharge exhaust gas from a second WHRSG or WHRPF exchanger upstream that is inlet-connected to a re-circulated exhaust gas manifold that conveys the combined reduced temperature exhaust gases originating from both the WHRU exchanger and the first parallel-positioned WHRSG or WHRPF exchanger into which the total cogeneration system's recoverable high temperature waste exhaust gases are ~~is~~ first inlet-connected.", the total amount of exhaust waste heat that can usefully be transferred into the said heat exchanger's supplied fluids is limited to (or in proportion to) the amount of turbine mechanical output power that is developed by the invention's power cogeneration system turbine unit.

The presented invention provides an alternative process and system apparatus devices by which the presented power cogeneration process and system's production of steam or hot water (or heating of process fluids) is independent of the amount of turbine developed mechanical power within the cogeneration system. This presented invention, with its described alternative added process stream and system apparatus devices, provides the means wherein added operational flexibility, increased thermal efficiency, and maintenance of the same ultra-low exhaust emissions are achieved. Wherein an example presented cogeneration system facility capable of a given mechanical power output rating could now fully utilize at all times a 100% or greater

steam production or process fluid heating than could be associated with the cogeneration process and system shown in Fig. 1, the Fig. 2 presented added alternative cogeneration process stream and system apparatus devices could satisfy this cited latest requirement. The invention's Fig. 2 description of the improved cogeneration process and system apparatus devices includes the added alternative process stream wherein the presented overall cogeneration system thermal efficiencies can significantly exceed 115% as shown later in Table 5 for an example 100% increase in steam or process heating beyond the Fig. 1 system capabilities.

The invention's presented added alternative process stream and system apparatus devices provide the collective means to provide supplementary conversion of fuel energy into useful recoverable heat within the overall partially-open power cogeneration cycle process. The cited added process stream's inlet communication to the Fig. 1 described partially-open power cogeneration cycle process and system therein comprises a conduit having connectivity to the end of the Fig. 1 recirculated exhaust gas distribution manifold, the conduit communicating recirculated exhaust gases to two end-connected Fig. 2 example preferred parallel-positioned auxiliary primary recycle blowers. The primary recycle blowers can be separately capacity-controlled to produce slightly re-pressurized first and second conduit stream flows of exhaust recycled gas that are connected to the recited process stream's inline-positioned oxy-fuel fired combustion burner assembly unit.

The cited oxy-fuel fired combustion burner assembly employs additional individual connected flow controlled streams of fuel and predominant oxygen gas mixture to produce an identical composition of combustion exhaust gases as comprising the power cogeneration partial-open cycle turbine exhaust gases. The added oxy-fuel fired

combustion burner assembly's exhaust gases are conduit routed into the turbine exhaust conduit branch connecting to the WHRSG exchanger or WHRPG exchanger described above in the above cited Second Embodiment text.

In the case of the Fig. 1 configuration of the presented invention's power cogeneration process and system apparatus assembly devices, any increase in power output generation (beyond the then existing cogeneration system's 'steady-state' production condition, but not exceeding the gas turbine's continuous rating) can be accomplished by terminating the controlled flow of vented excess turbine re-circulated exhaust flow to atmosphere and increasing the fuel flow and predominant oxygen gas flow. Only upon reaching the required accumulated increased mass flow of preset high temperature exhaust gases within the closed system, shall the presented invention's power cogeneration process and system then be returned to its normal 'steady-state' and 'partially-open system status' with controlled excess re-circulated exhaust gas vented to atmosphere.

Eighth Embodiment

From the First Embodiment cited "As shown in Table 1, between gas turbine fuel combustion pressures of 45 psia and 75 psia, the AES Simple Cycle thermal efficiencies can range between 35.16% and 43.24%." The invention's improved high thermally efficient power cogeneration method 's presented example 60 psia oxy-fuel combustion chamber assembly therein enables a low fuel supply pressure of less than 65 psi gage (5,5 Bar) to be employed.

Ninth Embodiment

From the preceding collective Embodiments' cited control of fluid stream flows, temperatures, pressures, generated power, and apparatus means includes valves,

compressors, blowers, motors, etc., the presented invention's power cogeneration process and system apparatus devices can be both performance and safety monitored and further controlled by a manufacturer's PLC based control panel. The PLC based control panel design that can meet or exceed the power cogeneration facility's applicable industry and governmental standards and codes, and as applicably applied to the power cogeneration method's specifically employed apparatus assembly devices.

Overall System and Apparatus Means

Within the presented improved power cogeneration system process and system and apparatus assembly devices described herein, the provided system employed oxy-fuel combustion generated working motive fluid means can provide a 95 to 100% reduction of NO.sub.x that occurs within current art Low-NO.sub.x gas turbines. The partially-open turbine gaseous thermal fluid energy cycle contained within the cited power cogeneration process provides a temperature controlled oxy-fuel combustion temperature and the speed of combustion flame heat transfer that also similarly suppresses the chemical reaction dissociation formation of the fugitive emission CO from CO.sub.2. The means of suppressing the development of fugitive emissions results from the following collective working motive fluid molecular attributes and combustion events:

(a) The working motive fluid of this invention's power cogeneration system process and apparatus devices comprises a continuous superheated mixture of predominant CO.sub.2 and H.sub.2 O in identical Mol percent ratio proportions as these molecular components are produced from the combustion of a given fuel. For example, in the case of landfill gas, the working gas fluid contains a 1:1 ratio of 2 Mol carbon dioxide to

2 Mols water vapor in identical proportion to the products of stoichiometric oxygen combustion. The chemical reaction equation can be described as follows:

Working Motive Fluid + 1 Mol CH.sub.4 + 1 Mol CO.sub.2 + 2 Mols O.sub.2 = 2 Mol CO.sub.2 + 2 Mol H.sub.2 O + Heat + Working Motive Fluid.

In the example of methane gas fuels, the working fluid composition contains a ratio of 1 Mol CO.sub.2 to 2 Mols H.sub.2 O in identical proportion to the products of 105% stoichiometric oxygen combustion of methane fuel within the chemical reaction equation of:

Working Motive Fluid + 1 Mol CH.sub.4 + 2.1 Mols O.sub.2 = 1 Mol CO.sub.2 + 2 Mols H.sub.2 O + 0.1 Mol O.sub.2 + Heat + Working Motive Fluid;

(b) The invention's power cogeneration system's process' working fluid provides the replacement mass flow means to conventional open power cycles incorporating the predominant diatomic non-emissive and non-radiant energy absorbing molecular component nitrogen (N.sub.2) within the cited-conventional cycles working motive fluid. The invention's replacement working motive fluid contains both predominant water vapor (with a binary lack of molecular symmetry) and a mass ratio of atomic weights of (16/2) = 8 and carbon dioxide with a mass ratio of atomic weights of (32/12) = 2.66, which denotes their susceptibility to high radiant energy emissivity and absorption. This compares to the nitrogen's mass ratio 14/14 = 1 which denotes nitrogen's minimal, if any, emissive and radiant energy absorbing abilities at any temperature;

(c) The presented invention's power cogeneration method's cycle system's controlled flow of working motive fluid into the oxy-fuel combustion chamber assembly therein provides the said assembly's interior gaseous environment with an approximate 900 % increase of binary molecular mass means susceptible to the fuel/oxidation

exothermic chemical reactions generated combustion heat transfer being highly accelerated at the speed of light (186,000 miles a second). The cited highly accelerated rate of combustion heat transfer to the highly predominant interior binary gases within the cited combustion apparatus assembly, provides the means by which a controlled highly superheated temperature equilibrium state of accelerated fuel and oxygen reaction rates is maintained without the prospect of developing CO_2 disassociation reactions that produces CO in the presence of the highly elevated gas molecular temperatures above 2600° F to 2900° F;

The cited binary gases being comprised of individual binary carbon dioxide and binary water vapor molecular gases whose individual molecular mass heat energies are separately emitted or adsorbed in their own individual and specific narrow and unique infrared spectral ranges.

The radiant heat is transferred from the cited binary carbon dioxide and binary water vapor combustion gaseous products in their specific Mol% proportions as determined by the molecular fuel being combusted, the said gaseous Mol% proportions being sustained within the recirculated (or recycle) and re-pressured exhaust gases (or working motive fluid) that enter the fuel combustion chamber assembly device along with supplied fuel and oxygen.

(d) The First Embodiment recited oxy-fuel combustion chamber assembly pre-mix sub-assemblies provides the means for homogeneous blending, wherein gaseous streams of working motive fluid and an oxygen-rich stream can be further homogeneously blended for downstream mixing and ignition with the gaseous fuel stream. The gaseous fuel stream also comprises binary molecules of high susceptibility to high radiant energy absorption and emissivity, such as methane with a mass ratio of

atomic weights of (16/4) = 4, ethane with a mass ratio of atomic weights of (24/4) = 6, propane with a mass ratio of atomic weights of (36/8) = 4.5, etc;

(e) The subsequent tertiary zone admission of a controlled-flow of Table 1 identified 1350° F superheated working motive fluid into the example 2400° F. combustion chamber assembly's primary oxy-fuel combined primary combustion flame zone and its outer secondary zone combustion gas stream, results in the rapid creation of the example desired equilibrium temperature of 1800° F. This rapid establishment of the preferred equilibrium temperature is due to the 186,000 miles per second rate of radiant heat transfer between the two streams of common molecular constituents with common means of high radiant energy absorption and emissivity in their respective individual infra-red spectrum ranges.

The presented improved power cogeneration process and system apparatus devices employ a partially-open gaseous thermal fluid energy cycle therein incorporating an oxy-fuel fired combustion system's apparatus assembly generated working motive fluid gases of optimum selected operating pressures and temperatures that can achieve 115% or greater power cogeneration facility thermal efficiencies. The means of achieving these 40% to 50% increased thermal efficiencies than those thermal efficiencies provided by current art conventional cogeneration power facilities (thereby reducing CO.sub.2 "greenhouse mass flow emissions" by 40% to 50%), results from the following improved power generation method and apparatus devices, employed partially-open gaseous thermal fluid energy cycle, and the collective working fluid molecular thermal characteristics or attributes comprising:

(a) The oxy-fuel combustion chamber assembly's low operating pressures reduces the work (per pound of primary recycled gas) that is adsorbed by the turbine train's

compressor apparatus assembly, the said compressor re-pressurizing the recycled gas stream that subsequently becomes the downstream highly superheated working motive fluid that is expanded through the hot gas expansion power output assembly;

(b) The presented improved power cogeneration process and system working motive fluid molecular gas composition replaces air content nitrogen that is the predominant mass flow molecular gas component in a conventional gas turbine working motive fluid. The presented improved power cogeneration process and system working motive fluid is unique in that each highly superheated temperature pound of fluid can adsorb or exchange approximately 42% more heat per degree Fahrenheit change in gas temperature than does air or nitrogen.

(c) In the presented example operating conditions, approximately 92% of the high temperature example gas turbine exhaust heat energy that is recovered from within the total exhaust flow passing through the WHRU exchanger and first WHRSG exchanger (or WHRPF exchanger) is transferred back into the pressurized working motive fluid that will re-enter the oxy-fuel combustion chamber assembly to further absorb the heat of fuel combustion.

(d) Approximately 92 to 95% of the presented improved power cogeneration process and system's re-circulated exhaust downstream of the waste heat exhaust exchangers (therein still containing a large 'heat sink' quantity of energy) can approximately be recycled within the closed portion of the improved power cogeneration process and system during steady-state operation. During an increased energy output demand on the presented power cogeneration process and system, 100% of the presented improved cogeneration process and system's re-circulated exhaust heat capacity

downstream of the waste heat exhaust exchangers can be recycled during its accompanying 'total-closed' cycle process and system operation.

(e) The presented improved power cogeneration process and system employed partially-open gaseous thermal fluid energy cycle, and the described operating characteristics of the continuous and uniform superheated gaseous heat transfer fluid, enables the presented power cogeneration method to annually maintain a continuous facility power output rating without any imposed site ambient temperature derations.

With the presented example partially-open turbine powered cogeneration process and system apparatus assembly devices described herein, or additionally including the presented added alternative process steam and system and employed apparatus assembly devices, either a modified conventional gas turbine power unit apparatus train or an unconventional turbine power unit train comprised of two or more apparatus assemblies can be employed. An alternative turbine assembly apparatus configuration can utilize separate existing low cost mechanical equipment components and combustion chamber and/ or combustion burner assemblies which can be predominantly not designed for, nor applied to, the manufacture of conventional gas turbines, nor the said components' incorporation into facility designs of current technology gas turbine power cogeneration facilities.

Within the presented power cogeneration partially-open cycle process and system apparatus assembly devices described herein, the presented invention provides an added alternative process stream and system apparatus assembly devices wherein a the power cogeneration system's production rate of steam or hot water (or heating of process fluids) can be independent of the actual percentage of full-rated mechanical or

electric power load that is being produced from the described power cogeneration system.

Within the presented power cogeneration process and system apparatus assembly devices described herein, the system's apparatus assembly devices are provided wherein all fluid streams entering the oxy-fuel combustion chamber assembly (and alternative combustion burner assembly) are controlled to maintain preset maximum combined primary combustion flame zone and outer secondary zone temperatures in which a non-distribution quality of gaseous hydrocarbon fuel (containing toxic and/or difficult to combust hydrocarbon molecular gases) can be rapidly carried through the oxy-fuel combustion process to a useful heat energy conversion and/or completed high temperature incineration without significantly altering the process and system's high thermal efficiencies or ultra-low emission levels.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a schematic flow diagram of the invention's improved power cogeneration process and system method and apparatus devices employed within a partially-open gaseous thermal fluid energy cycle therein incorporating an example modified configuration of a conventional gas turbine power unit and simplified waste heat transfer apparatus for either steam or hot water generation, or process fluid heating.

Fig.2 is a schematic flow diagram of the invention's improved cogeneration process and system that includes the presented partially-open gaseous thermal fluid energy cycle of Fig. 1, and additional alternative example comprising a non-conventional turbine power engine unit and apparatus assembly devices including an alternate separate motor or steam turbine driven recycle or recirculated exhaust gas compressor,

an oxy-fuel combustion chamber assembly series-connected to a hot gas expander turbine device, and an alternative supplementary blower/oxy-fuel fired combustion burner assembly that can sustain rated steam or hot water production or heating of process fluids irregardless of the said example non-conventional turbine power engine unit's output of mechanical or electric power.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now more particularly to Fig. 1, an example modified conventional gas turbine power unit's primary recycle gas compressor section **1** comprises one or more recycle exhaust gas compression stages, positioned in series, with a final stage of radially directed discharge flow of compressed or re-pressurized recirculated exhaust gas. In the case of a two-shaft turbine power unit, the power to drive the primary recycle gas compressor section **1** is transmitted by shaft **2**, on which one or more high-pressure power extraction turbine stages are mounted within the combustion hot gas expansion power turbine assembly **3**. The second shaft, designed for mechanical equipment or generator drive applications, has one or more low-pressure hot gas expansion power stages mounted on power output shaft **4**, with coupling means for power transmission to rotate the driven equipment.

The invention's improved power cogeneration process adaptation to modified conventional gas turbine engine driven mechanical equipment may or may not require the addition of a gearbox or variable speed coupling **5** to adapt the speed of the hot gas expansion power turbine assembly **3** to the speed required by a generator or other driven equipment (not shown). The rotating driven equipment may have its required power transmitted through a shaft and coupling device **6**. The shaft and coupling means

device **6** can transmit power to a generator **7**, wherein electric power is produced and transmitted through conduit means **8** to a control room module **9**. Control room module **9** therein can contain the turbine power unit's PLC control panel, electrical switchgear, and motor control center, whereby electric power production is controlled and distributed to the power cogeneration facility's electrical grid and/or connected electric utility electrical grid. The shaft and coupling device **6** may alternately transmit power to other rotating pumps or compressors (not shown) in lieu of generator **7**.

Within the presented invention's improved power cogeneration process and system, including a partially-open gaseous thermal fluid energy cycle and apparatus devices, the slightly superheated example turbine power unit exhaust re-circulated gas flows from the example turbine power unit exhaust gas distribution manifold **10** (having end-connection **62** that is blind-flanged closed in this Figure 1) through said manifold side-branch connected example turbine power unit exhaust recycle gas conduit means **11** that is end-connected to the inlet of the turbine power unit's exhaust gas primary recycle compressor section **1**. The higher-pressure and higher-temperature compressed recycle turbine power unit's discharged gas (hereafter referred to as "primary re-pressurized recycle gas") is routed through conduit manifold **12** containing two parallel conduit end-branches **13** and **14** respectively, either one or both said conduit branch therein containing a gas mass flow sensor means and a flow control (or flow proportioning) damper valve **15**.

The twin parallel conduit end-branches **13** and **14** respectively convey first and second primary re-pressurized recycle gas streams with respective end connections to parallel inlet headers **16** and **17** located on the section **18** of the example turbine power unit's exhaust gas waste heat recovery unit (hereafter may be referred to as WHRU)

exchanger. The said first and second streams of primary re-pressurized recycle gas is discharged from section **18** of the cited turbine power unit's WHRU exchanger through outlet headers **20** and **19** respectively at highly increased superheated temperatures (with the highly superheated recycle gas hereinafter referred to as a "working motive fluid") with flows through conduits **21** and **22** respectively.

The primary re-pressurized recycle gas additionally can be routed at low gas flow levels from conduit manifold means **12** through a side-branch connected conduit means **23** containing motor driven air-cooler **24** and flow control valve **25** for subsequent downstream conduit end-connection to one or more partial-premixer sub-assemblies **27** that can be contained within one or more oxy-fuel combustion chamber assembly **26**, the said assembly may therein preferably be conventionally positioned radially about the centerline axis of the turbine power unit assembly.

Conduit **22** conveys the second controlled stream of working motive fluid to the internal primary combustion zone **28** contained within each oxy-fuel combustion chamber assembly **26.** Conduit **21** conveys the first controlled stream of working motive fluid to the internal tertiary blending zone **29** contained within each oxy-fuel combustion chamber assembly **26** that can be positioned radially about the centerline axis of the turbine assembly. The combined streams of working motive fluid composition gases exiting tertiary blending zone **29** can be routed through conduit flow means **30** having end connection to the inlet of the hot gas expansion power turbine assembly **3.**

Alternately the conduit **21** can convey the first controlled stream of working motive fluid to a common single tertiary blending zone that receives primary combustion zone working fluid composition gases from two or more oxy-fuel combustion chamber assembly **26** that is positioned immediately upstream of the described alternate single

common (not shown) tertiary blending zone. The combined streams of working motive fluid composition gases exiting the common tertiary blending zone (not shown) are routed through conduit **30** having end connection to the inlet of the hot gas expansion power turbine assembly **3**.

A pressurized stream of presented example methane fuel gas (or alternate acceptable liquid hydrocarbon fuel) is supplied from source **31** into conduit **32** that therein can contain sensor-transmitter devices for temperature, pressure, mass flow, and a fuel flow control valve device **33**, with said conduit having end–connectivity to either one or more preferred downstream partial-premixer subassembly **27** contained within oxy-fuel fired combustion chamber assembly **26.**

A controlled pressurized stream of predominant oxygen gas is supplied from a facility remote source **34** into conduit **35** that may contain sensor-transmitter devices for oxygen %, temperature, pressure, mass flow, and a flow control valve device **36**, with said conduit having end-connectivity to either one or more preferred partial pre-mix subassembly **27** contained within oxy-fuel combustion chamber assembly **26.**

Within the partial-premixer subassembly **27**, the said identified conduits **23**, **32**, and **35** respectively supplied controlled stream flows of primary re-pressurized recycle gas, fuel, and predominant oxygen are therein partially blended therein for following downstream ignition and controlled temperature combustion within the temperature sensor-transmitter monitored primary combustion zone **28** therein having further admitted second controlled stream of working motive fluid composition gases supplied by conduit **22.**

Within oxy-fuel fired combustion chamber assembly **26**, the combined mass flow of products of fuel combustion and streams of working motive fluid composition gases

flows from the primary combustion zone **28** at a controlled highly superheated presented example equilibrium temperature of 2400F into the downstream positioned tertiary blending zone **29** wherein these said gases are blended with the controlled mass flow of fore-described conduit **21** supplied first stream of working motive fluid composition gases.

The combined working motive fluid composition gases' mass flows entering the tertiary blending zone **29** within oxy-fuel fired combustion chamber assembly **26**, mixing together with primary combustion zone gases, therein produces a resultant selected equilibrium temperature and mass flow rate of superheated working motive fluid gases through conduit **30** into the hot gas expander power turbine subassembly **3**. Work is developed within the hot gas expander power turbine subassembly **3,** and the heat energy or enthalpy (Btu/lb) contained within the mass flow of expanded and exhausted working motive fluid gases is decreased and discharged into conduit **37**. Conduit **37** routes the hot gas expander power turbine subassembly exhaust gases through conduit end-branches **38** and **41** that are respectively connected to WHRU exchanger **18** and waste heat recovery steam generator (herein after may be referred to as WHRSG) or waste heat recovery process fluid heater (herein after may be referred to as WHRPF) exchanger **42.** The proportional division of the total mass flow of the hot gas expander power turbine subassembly **3** exhaust gas contained within conduit **37,** between conduit end-branches **38** and **41,** can be flow-controlled or flow-proportioned respectively by damper valves **40** and **44** contained within the WHRU exchanger **18** and WHRSG or WHRPF exchanger **42** respective outlet exhaust branch conduits **39** and **43.** The predominant portion of conduit **37**'s total mass flow of exhaust gases is divided and directed through WHRU exchanger **18** to satisfy the working motive fluid exhaust heat

transfer requirements to the cited lower temperature primary re-pressurized recycle gas flowing through exchanger **18**.

In the case of waste heat transfer to a power cogeneration facility's supplied hot water/steam or process fluid circuit, a pressurized stream of a power cogeneration facility's steam condensate feed water (or process fluid) can be supplied from source **46** into conduit **47** that can therein contain sensor-transmitter devices for both temperature and mass flow, and having end-connectivity to the inlet header **48** of a second WHRSG or WHRPF exchanger **49**. In the case of stream generation, the supplied stream of steam condensate can be changed from a liquid phase to a liquid/vapor 2-phase state or slight superheated steam vapor state within exchanger **49**, and exits from exchanger **49** through discharge header **50** into conduit **51** having end-connectivity to the inlet header **52** of the first WHRSG exchanger **42**. Within WHRSG exchanger **42**, the steam circuit stream can be highly superheated as desired to provide a power cogeneration produced steam superheat temperature that can range from less than 900°F to over 1200°F for discharge from outlet header **53** into conduit **54** end-connected to delivery point **55.** For the alternative addition of the presented improved power cogeneration method's system having increased or independent mass flow steam generation (as described later in Figure 2), the hot gas expansion power turbine subassembly exhaust gas conduit **37**'s end-branch conduit **41** can be supplied with a connected side-branch conduct **56** whose end flange connection **57** can be closed with a blind-flange cover in Figure 1.

The presented power cogeneration process and system's reduced temperature exhaust gases exits from the WHRU exchanger **18** and the parallel-positioned WHRSG exchanger or WHRPF exchanger **42** (as earlier recited) through their respective

exhaust gas discharge branch conduits **39** and **43**, each branch conduit respectively therein can contain controlled-flow damper valves **40** and **44**. The reduced temperature re-circulated exhaust gas flows from branch conduits **40** and **44** are combined within re-circulated exhaust gas manifold **45** having end-connectivity to a downstream-positioned second WHRSG exchanger or WHRPF exchanger **49.** The improved power cogeneration process' re-circulated exhaust gases are reduced in temperature within the second WHRSG exchanger or WHRPF exchanger **49** to a temperature that can be slightly above the dew point temperature of the re-circulated exhaust gas as it is discharged from the heat exchanger **49** into the exhaust gas distribution manifold **10**.

Within the presented invention's power cogeneration method included partially-open gaseous thermal fluid energy cycle and apparatus devices, the slightly superheated example turbine power unit's re-circulated exhaust gas mass flow within exhaust gas distribution manifold **10** remains at a constant flow rate during steady-state power cogeneration thermal energy conversion operations. During the recited steady-state operation, the recited method's generated excess of slightly superheated re-circulated exhaust gas mass flow within manifold **10** can be flow-directed from manifold **10** through side-branch conduit **58** having downstream connectivity to atmosphere at vent point **61,** and said conduit may therein contain back pressure control valve **59** and flow control valve **60**. The terminal end of exhaust gas distribution manifold **10** is provided with a closed blind flange connection **62** in Fig.1.

Fig.2 is a schematic flow diagram of the invention's improved power cogeneration process and system as shown in Fig. 1, but therein having specifically added described alternative apparatus assembly devices that can include both an alternate separate motor or steam turbine driven recycle gas compressor and an oxy-fuel combustion

chamber assembly that is series-connected to a separate hot gas expander turbine ~~with~~ having an output power shaft. Fig.2 further shows the improved power cogeneration process having an added alternative process and system stream incorporating recirculated exhaust gas blowers and a separate oxy-fuel fired combustion burner assembly that performs the function of a supplementary hot exhaust gas generator ~~to~~ that can increase the power cogeneration system's method production of either steam, hot water, or the heating of process fluids.

Referring now more particularly to Fig. 2, the cited alternative separately driven primary recycle gas compressor **63** can comprise one or more recycle gas compression stages, with a final gas compression stage that can incorporate an outward radially-directed discharge flow of re-pressurized recycle gas. The recycle gas compressor **63** can alternately be directly driven by either an electric motor or a steam turbine type driver **64**, or the said compressor indirectly-driven through either gearbox or variable speed coupling assembly device **65.** The recited hot gas expander power turbine assembly **67** can comprise one or more power extraction turbine stages and an assembly output shaft that can be directly connected to electrical generator **7** wherein electric power is produced and transmitted through conduit means **8** to a control room module **9**. Control room module **9** therein contains the power cogeneration system's PLC control panel, and an electrical switchgear and motor control center which provides the means by which electric power production can be controlled and distributed to the operating facility's electrical grid and/or to the utility electrical grid. Alternately (not shown), a gearbox or variable speed coupling can be positioned between the power turbine assembly output shaft and alternative driven rotating pumps or compressors (not shown) in lieu of generator **7**.

Referring now more particularly to Fig. 2 and the flows of thermal fluids within the partially-open gaseous thermal fluid energy cycle contained within the presented invention's improved power cogeneration process and system containing alternative apparatus assembly devices. The slightly superheated recirculated cycle exhaust gas can flow from the recycle exhaust gas distribution manifold **10** with exiting flows through open end-connection **62** that series-connects to manifold extension conduit **68** as further described later. Manifold **10** side-branch connected recirculated cycle exhaust gas conduit means **11** is end-connected to the inlet of the primary recycle gas compressor **63**. The higher-pressure and higher-temperature re-pressurized recirculated cycle exhaust gas (hereafter referred to as "primary re-pressurized recycle gas") and related identical stream flows are thereafter the same as described as in Fig.1 for its routing through WHRU **18** and continuing to oxy-fuel fired combustion <u>chamber</u> assembly **26.** The highly superheated working fluid gases emitted from the oxy-fuel combustion chamber assembly **26** are routed through direct-connected gas transition assembly **66** with end connectivity to the inlet of the hot gas expander power unit assembly **67**.

Conduit **37** routes the hot gas expander unit assembly **67** exhaust gases through conduit end-branches **38** and **41** that are respectively connected to WHRU exchanger **18** and WHRSG or WHRPF exchanger **42** and thereafter described associated conduit streams are as described for Fig.1. For the alternative addition of increased cogeneration process' developed additional thermal heat for transfer to steam, hot water, or process streams, fore-described conduit **68** can route a flow of slightly superheated exhaust recycle gas through preferred parallel end-branch conduits **69** and **70** that respectively can contain flow proportioning or flow control provided

isolation/damper valves **71** and **72** and having end connectivity with one or more parallel-positioned **73** and **74** speed-controlled motor-driven exhaust recycle gas blowers. Exhaust recycle gas blower **73** provides a required mass flow of exhaust recycle gas at a slightly increased pressure into its discharge conduit **75** having end-connectivity with the tertiary blending zone **82** contained within the downstream-positioned oxy-fuel fired combustion burner assembly **79.** Exhaust recycle gas blower **74** provides a required mass flow of exhaust recycle gas at a slightly increased pressure into its discharge conduit **76** having end-connectivity with the partial-premixer subassembly **80** contained within the downstream-positioned oxy-fuel fired combustion burner assembly **79.**

A controlled stream of low pressure predominant oxygen gas mixture is supplied from facility remote source **77** into conduit **84** that can contain sensor-transmitter for oxygen %, temperature, pressure, mass flow, and oxygen flow control valve device **85**, with said conduit **84** having end-connectivity to either one or more preferred partial-premixer subassembly **80** contained within oxy-fuel fired combustion burner assembly **79.**

A low pressure stream of presented example methane fuel gas (or alternate acceptable liquid hydrocarbon fuel) is supplied from source **78** into conduit **86** that can contain sensor-transmitter means for temperature, pressure, mass flow, and fuel pressure/flow control valve means **87**, with said conduit **86** having end--connectivity to either one or more downstream-positioned preferred partial-premixer subassembly **80** contained within oxy-fuel fired combustion burner assembly **79.**

Within the partial-premixer subassembly **80**, the said identified conduits **76**, **86**, and **84** respectively supplied stream flows of exhaust recycle gas, fuel, and predominant

oxygen gas mixture are therein blended for following downstream ignition and controlled temperature combustion within the temperature sensor-transmitter monitored primary combustion zone **81** contained within oxy-fuel fired combustion burner assembly **79.**

Within oxy-fuel fired combustion burner assembly **79**, the predominant mass flow of combined products of fuel combustion and exhaust recycled gas therein flows from the primary combustion zone **81** (at a controlled high superheated presented example equilibrium temperature of 2400F) into the downstream tertiary blending zone **82** wherein these said composition gases can be blended with the controlled mass flow of fore-described conduit **75** supplied blower discharge stream of slightly re-pressurized and low superheated exhaust recycle gases of identical molecular and Mol% gas composition to those gases flowing from **81.**

The oxy-fuel fired combustion burner assembly **79** provides a supplementary mass flow of slightly re-pressurized and highly superheated exhaust gas at controlled temperatures into conduit **83** having end connectivity to conduit **56**'s flanged connection **57**. The supplementary mass flow of slightly re-pressurized and highly superheated exhaust gas is routed through conduit **56** into branch conduit **41** having connectivity to WHRSG exchanger or WHRPF process fluid exchanger **42**, thereby enabling a an increased mass flow of steam or hot water or process fluids (in conduits **47**, **51**, and **54** at selected desired temperature operating conditions) to be transmitted through the WHRSG or WHRPF exchangers **49** and **42.** The described supplementary mass flow of slightly re-pressurized and highly superheated exhaust gas through conduit **56** therein augments the flow of turbine exhaust flowing through conduit **41** end connected to the WHRSG or WHRPF.

Within the presented invention's improved power cogeneration system method, the slightly superheated recirculated cycle composition exhaust gas mass flow within conduit **11** remains at a constant flow rate for steady-state example hot gas expansion turbine shaft horsepower output production. The excess slightly superheated recirculated exhaust gas mass flow within manifold **10** that is not required for steady-state power production, nor is required to maintain an existing steady-state recycle exhaust gas mass flow rate within conduit **68** for the oxy-fuel fired combustion burner assembly **79**, is flow-directed from manifold 10 through side-branch conduit **58** that can contain back pressure control valve **59** and flow control/isolation valve **60** with downstream connectivity to atmosphere occurring at vent point **61**.

The numbers in Table 2 below are representative of: one example set of fluid stream conditions in which the presented cogeneration process and system can operate (the conduit streams are those identified by the numbers in Fig. 1). The following assumptions were made: the recycle gas compressor efficiency and hot gas expansion turbine efficiency are both 84%; the oxy-fuel combustion burner assembly operating pressure is 60 psia; and the methane fuel gas flow rate is 1 Mol/minute.

TABLE 2

Conduit Stream Number	Stream Fluid	Temperature Degree F.	Pressure PSIA	Mass Flow lbs./Min.
11	Recycle Exhaust	197	15	1879
12	Compressed Recycle	500	64	1879
22	WMF – Primary Zone	1350	63	686

21	WMF – Tertiary Zone	1350	63	1153
23	Cooled Compressed Recycle	280	63.5	40
32	Methane Fuel	70	85	16
35	Predominant O.sub.2	110	65	64
30	Combustion Working Motive Fluid	1800	60	1959
37	Turbine Engine Exhaust	1391	15.8	1959
45	WHRU & WHRSG Exhaust	530	15.4	1959
58	Cogen System Method Vent Gas	197	15.1	81

(WMF) = Working Motive Fluid

With the same example stream conditions and assumptions made for Table 2, supra, Table 3 provides the thermodynamic values from which the tabulated compressor horsepowers and example power unit power outputs are derived.

TABLE 3

Conduit Stream ** Number	Rotating Equipment Name	Stream Fluid	Temperature Degrees F	Mass Flow lbs./Min.	Delta Enthalpy Btu/Lb.	Horse-Power (HP)
11 to 12	Exhaust	Inlet	197			
	Recycle			1879	98.9	4377
	Compressor	Discharge	500			
30 to 37	Hot Gas	Inlet	1800			
	Expander			1959	169.7	7837
	Turbine	Discharge	1391			
				Net Shaft Horsepower Output		3460 SHP *

(*) Note: (20,693,400 LHV Btu/Hr-Mol CH4) ÷ 3460 SHP = 5980 Btu/Hp-hr. fuel rate.

(*) Note: Fuel Rate: (2545 Bt/Hp-hr.÷ 5980 Btu/Hp-Hr. = 42.55% turbine engine thermal efficiency:

(**) Note: Only the conduit stream numbers reference to both Figure 1 and Figure 2 drawings.

With the same conditions and assumptions made for Table 2, supra, Table 4 contains six conduit streams (as noted) that appear in both Fig. 1 and Fig. 2, with the thermal heat transfers and mass flow rates pertaining only to the Fig. 1 presented improved power cogeneration process and system apparatus assemblies.

TABLE 4

Conduit Stream Number	Heat Exchanger Name	Stream Fluid	Temperature Change Degrees F	Mass Flow lbs./Min.	Delta Enthalpy Btu/Lb.	Recovered Heat Rate Btu/Min.
37 to 45	18 + 42	Total Exhaust	1391F to 530F	1959	326	638,634
38 to 39	WHRU 18	Exhaust Gas	1391F to 530F	1805.15	326	588,480
13/14 - 21/22	WHRU 18	'WMF' Gas	500F to 1350F	1839	320	588,480
41 to 43	WHRSG 42	Exhaust	1391F to 530F	153.85	326	50,154 *
45 to 10	WHRSG 49	Exhaust	530F to 197F	1959	110	215,490 *

*Total Available Heat for Process Gas or Steam Circuit = (215,490 + 50,154) = 265,644 Btu/Min.

*Total Available Heat for Process Gas or Steam Circuit= (265,644 Btu/Min. x 60) = 15,938,640 Btu/Hr.

Total 910 Btu/SCF LHV of 1 Mol/Min. Methane Fuel Gas = 344,890 Btu/Min. = 20,693,400 Btu/Hr.

Recovered Heat Rate from the Supplied Fuel Gas Energy:

= (15,938,640 Btu/Hr ÷ 20,693,400 LHV Btu/Hr-Mol Methane Gas) = 77.02%.

Total Improved Cogeneration Process and System Thermal Efficiency:

= 42.5% Simple Cycle Turbine Unit Energy Conversion Efficiency

+ 77.02% Recovered Heat Rate

= 119.5%.

With the same conditions and assumptions made for Table 2 and 4 supra, Table 5 provides the thermal heat transfers and mass flow rates as contained within the Alternative Cogeneration Process System of Fig.2 with added supplementary heat blended into the hot gas expansion turbine exhaust stream to increase the

cogeneration process and system's apparatus assemblies effective transfer of heat to steam or process heated fluids by the example amount of 100%.

TABLE 5

Conduit Stream Number	Heat Exchanger Name	Stream Gas	Temperature Change Degrees F	Mass Flow lbs./Min.	Delta Enthalpy Btu/Lb.	Recovered Heat Rate Btu/Min.
38 to 39	WHRU 18	Turbine Exh.	1391F to 530F	1805	326	588,480
13/14 - 21/22	WHRU 18	'WMF' Gas	500F to 1350F	1839	320	588,480
41/83 - 43	WHRSG 42	Exhaust	1391F to 530F	763	326	248,738 *
45 to 10	WHRSG 49	Exhaust	530F to 197F	2568	110	282,480 *
10 to11		Recycle		1879		
10 to 68		Recycle	197F	556		
10 to 61		Exhaust Vent		138		
35 + 84		95% Oxygen Mixture	120F	112		
32 +86		Methane Fuel	70F	26		

*Total Available Effective Energy Conversion to Heat for Process Gas or Water/Steam Circuit:

= (248,738+ 282,480) = 531,218 Btu/Min. = 31,873,080 Btu/Hr.

Turbine Power Apparatus Effective Energy Conversion Rate = (2545)x(3460 SHP) = 8,805,700 Btu/Hr.

Total Effective Energy Conversion Rate = 40,678,780 Btu/Hr.

Total System Fuel Energy Consumption:

(20,693,400 LHV Btu/Hr. for Turbine Apparatus+ 12,993,602 LHV Btu/Hr for Supplementary Oxy-Fuel Burner System) = 33,687,002 LHV Btu/Hr.

Overall System Thermal Efficiency: (40,678,780 Btu/Hr.) ÷ (33,687,002) = 120.75%

It should be understood that the forgoing description is only illustrative of the invention. Various altered method system and apparatus alternatives, fuels, and modifications to operating conditions can be devised by those skilled in the art without

departing from the invention. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances which fall with the scope of the following appended claims.